Simulations of globular clusters merging in galactic nuclear regions

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Summary. We present the results of detailed N-body simulations regarding the interaction of four massive globular clusters in the central region of a triaxial galaxy. The systems undergo a full merging event, producing a sort of 'Super Star Cluster' (SSC) whose features are close to those of a superposition of the individual initial mergers. In contrast with other similar simulations, the resulting SSC structural parameters are located along the observed scaling relations of globular clusters. These findings seem to support the idea that a massive SSC may have formed in early phases of the mother galaxy evolution and contributed to the growth of a massive nucleus.

1 Introduction

In the paper [11], we analyzed the head-on collision between two globular clusters (GCs) moving on quasi-radial orbits in the galactic central region, with the aim, also, to understand how effective is the cluster tidal destruction. One of the main findings was that sufficiently compact clusters (initial King concentration parameter $c \geq 1.6$) keeps bound a substantial amount of their mass up to the complete orbital decaying. Another important result is that the orbital energy dissipation due to the tidal interaction is of the same order of that caused by dynamical friction (df). In light of these results, and given that df was shown to be important indeed in segregating massive GCs in triaxial potentials ([13, 4]), a natural further step in our investigation program is to study the possible merging of a set of GCs decayed in the central galactic region and the relevant characteristics of the super star cluster (SSC) they eventually form.

Furthermore, this topic is connected with the problem of the origin and formation history of the various kinds of SSCs recently observed in form of ultracompact dwarf galaxies ([5]), young massive clusters in starburst regions of interacting galaxies ([9]), and nuclear clusters in the central regions of early-type spirals ([3, 14]). One of the

most debated questions is whether they formed from the condensation of primordial gas clouds or through the "dissipationless" merging of smaller subunits. Recent indications coming from some N-body simulations ([7, 1, 2]) are in favour of this latter hypothesis. In this work we studied the merging process among massive GCs already decayed in the central region of a triaxial galaxy, including tidal distortion and df.

2 The model

The galactic environment in which GCs are embedded is represented by an analytical potential derived from the self-consistent *triaxial* model described in [6] (see also [11]). The galactic core radius is 200 pc, the core mass is 3×10^9 $\mathrm{M}_\odot$ with a central density $\rho_{g0} = 375$ $\mathrm{M}_\odot \mathrm{pc}^{-3}$. The deceleration due to df on the stellar motion is considered through a generalization of the Chandrasekhar formula to the triaxial case ([12]). The four simulated GCs have an initial internal distribution sampled from King isotropic models with total mass, central velocity dispersion and half-mass radius ranging, rispectively, in $M \simeq 42$–54×10^6 $\mathrm{M}_\odot$, $\sigma \simeq 25$–36 km s^{-1}, $r_c \simeq 11$–19 pc. The reference frame has the origin at the galactic center and the x and z axes are, respectively, along the maximum and minimum axis of the triaxial ellipsoid. The clusters were initially located within 100 pc from the galactic center. We represented each GC with $N = 2.5 \times 10^5$ 'particles', simulating their dynamics by means of the parallel 'ATD' treecode ([10, 11]).

3 Results

From Fig. 1 it can be clearly seen that the merging occurs rather quickly, i.e. in less than 20 galactic core crossing time ($\sim$ 14 Myr), after which the resulting system attains soon a dynamical equilibrium configuration, as confirmed by the evolution of the lagrangian radii that are nearly constant throughout the duration of the simulation ($\sim$ 35 Myr)

The final SSC morphology is that of an axisymmetric ellipsoid (axial ratios 1.4 : 1.4 : 1, ellipticity $\simeq 0.3$) without figure rotation. Nearly all the progenitors mass ends up into the SSC, which shows a central velocity dispersion $\sigma_0 \simeq 150$ km s^{-1} and a half-mass radius of $r_h \simeq 40$ pc. This means that the SSC is located much closer to the σ_0–M scaling relation followed by GCs than to that of elliptical galaxies (Fig. 2 lower panel), contrarily to what found by [2, 7]. This is probably due to that our system is located deep inside the galaxy potential well. Indeed, if one uses the virial relation to estimate the system total mass, $M = 7.5\sigma_0^2 r_h/G$ ([8]), then the location approaches the elliptical galaxies scaling law (Fig. 2).

The radial density profile of the SSC (Fig. 3) is similar to that given by the 'sum' of the initial profiles of the progenitors, with a central density a factor only 1.7 smaller and a slightly shallower profile outwards. This is in the direction of supporting the validity of the nuclear accretion model, suggested by [4]. Finally, we found that the SSC formed in the simulation without df, reaches an equilibrium state with similar morphological features, though in a nearly doubled time-scale and with a $\sim$ 3 times lower central density.

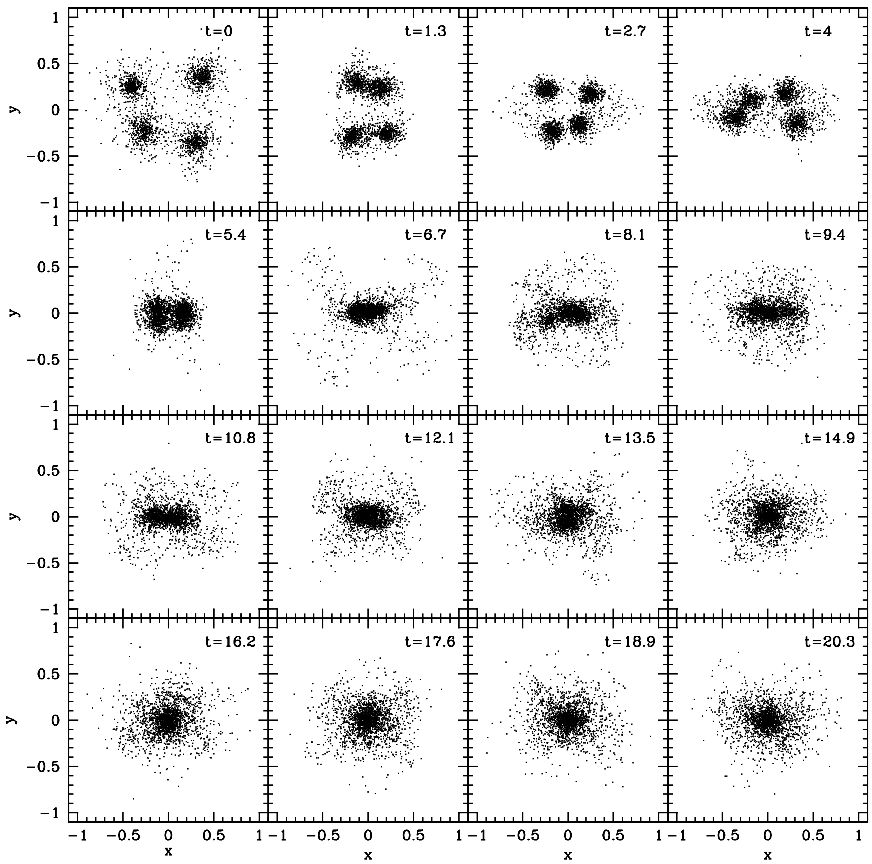

Fig. 1. Snapshots of the merging event (projection on the x–y plane). The labelled time is in unit of 0.8 Myr. Each snapshot size is $\sim$ 400 pc.

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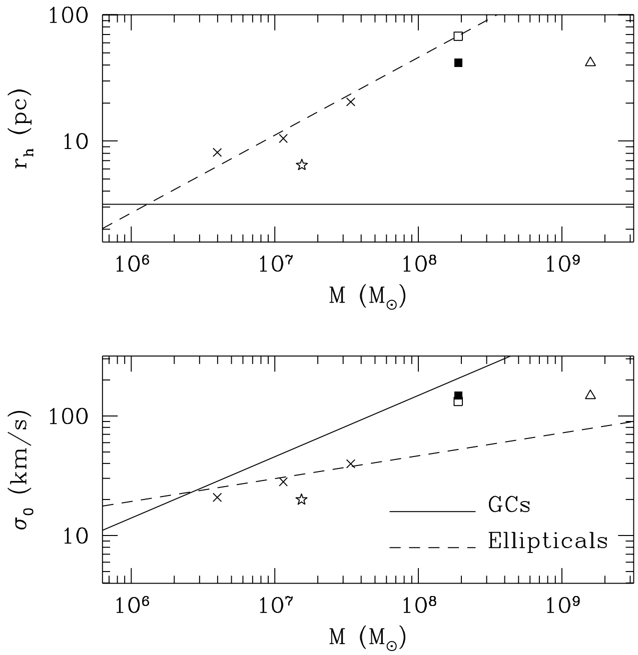

Fig. 2. Scaling relations for the last configuration of our SSC. The best fit relations for GCs and elliptical galaxies are also reported. The squares indicate the location of our SSC in the case where df is present (filled) or not (open), and when M is estimated by the virial relation (open triangles). The merging remnants locations for some of the cases simulated by [2] (crosses) and by [7] (stars) are also plotted.

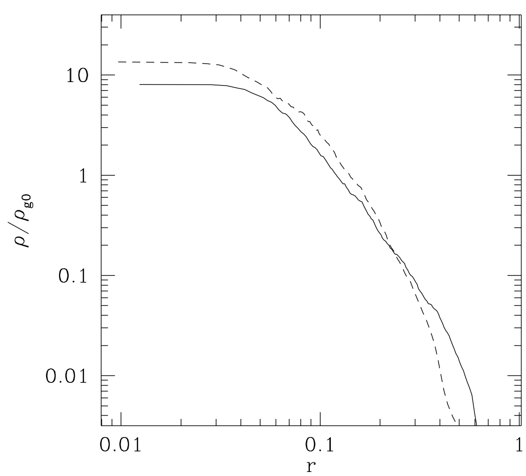

Fig. 3. Radial density profile of the SSC (solid line), compared with the profile given by the sum of the initial density distributions of the progenitors clusters (dashed line). The distance r (in units of 200 pc) is to the galactic center.

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